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A GRASP-PR Algorithm for the Vehicle Routing Problems with Product Pickups and Deliveries

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The effective management of forward and reverse product flows has become a crucial concern for modern companies seeking to integrate reverse logistics as a viable business activity. Depending on the nature of product returns, the design of combined distribution-collection systems seems to be the answer for effective and balanced flows of freights merging products brought to the customer as well as products returned to the depot. In the real life context, the implementation of backhauling strategies is common and appears in many different sectors. Clearly, such a practice may improve significantly the productivity and utilization of the vehicle fleet, reduce the resulting transportation costs, and increase the corresponding customer service levels.

On the basis of the above, the main focus is to study one-to-many-to-one vehicle routing problems with both pickup and deliveries. The most studied are the so-called Vehicle Routing Problem with Clustered Backhauls (VRPCB) (Jordan and Burns, 1984) and the Vehicle Routing Problem with Mixed Backhauls (VRPMB) (Golden et al., 1985); and they can be formally described as follows: Given a homogeneous fleet of depot-returning vehicles with identical capacities, the goal is to design a set of minimum cost vehicle routes to satisfy the delivery and pickup requirements of a set of geographically scattered customers. Each customer has a known demand either for delivery (linehaul) or pickup (backhaul), and must be visited only once by exactly one vehicle. The load of a vehicle must not exceed vehicle's maximum capacity. In some cases, the total distance traveled by each vehicle must also not exceed a predefined limit (route duration restrictions), while all vehicles during the service of customers must remain at the customer locations for a predefined amount of time (service time) if required. Considering the VRPCB, a predefined number of vehicles should be used, regardless the fact that better solutions can be obtained using either fewer or more vehicles. Additionally, if a route contains both linehaul and backhaul customers, then the backhaul customers must be served after the linehaul customers. Note also that a route is not allowed to consist entirely of backhaul customers. On the other hand, considering the VRPMB neither fleet size restrictions nor visiting sequence constraints are imposed. Hence, linehaul and backhaul customers can be freely mixed along a vehicle route; however, the accumulated vehicle load should not exceed the maximum capacity at any time along its route as the corresponding vehicle load fluctuates during the service of different types of customers. The objective for both problem settings is to minimize the total distance traveled.

The proposed approach evolves a set of reference solutions on the basis of an innovative Path Relinking framework. Initiating from a set of diverse trial solutions generated via an effective Greedy Randomized Adaptive Search Procedure (GRASP) (Feo and Resende, 1995), subsets of intermediate solutions are produced iteratively via a sophisticated Path Relinking (PR) (Ho and Gendreau, 2006) procedure that incorporates several ruin-and-recreate multi-parent recombination mechanisms. On this basis, initial provisional solutions are constructed and they are used as starting points for generating search trajectories towards elite guiding solutions. The proposed path generation procedure incorporates two edge-exchange structures for variation and also benefits from tunneling, assuming that capacity constraints are relaxed. To that end, promising intermediate solutions generated during the PR process are selected and further improved via a Guided Local Search (GLS) (Voudouris and Tsang, 1999) algorithm. The latter is also employed during the GRASP initialization phase as the primary local search improvement method. Finally, a deterministic set of rules are followed to manipulate and update the reference set. These rules ensure convergence velocity and evolution reliability, since they measure attractiveness not only in terms of solution quality, but also in terms of Hamming distances among the reference solutions.

Various computational experiments performed to evaluate the proposed solution algorithm using the benchmark data sets suggested by Goetschalckx and Jacobs-Blecha (1989), Toth and Vigo (1997), Salhi and Nagy (1999) and Dethloff (2001). Compared to the current state-of-the-art solution methods for the VRPCB and the VRPMB, the proposed solution approach proved to be highly competitive for both medium and large scale problem instances. Overall, the proposed method managed to produce new best solutions for several not optimality solved test problems via existing exact approaches, while in almost all cases the best reported cumulative and mean results are also improved.

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